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Drifting and blowing snow measurements: comparison between Snow Particle counter and a simple photoelectronic fork sensor (Wenglor)

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RESUME : L'hétérogénéité de la répartition de la neige en haute montagne a pour effet d'augmenter le risque d'avalanche. En Antarctique le transport de neige par le vent joue un rôle important sur le bilan de masse et par conséquent sur le niveau de la mer. Il est donc nécessaire d'évaluer le transport de neige par le vent sur le terrain en termes de quantité de neige transportée, d'occurrence d'événements et cela par des mesures automatiques. Nous présentons ici deux dispositifs de mesures basés sur le même principe d'obstruction de faisceau optique: le Snow Particules Counter et le capteur Wenglor YH08PCT8. Le SPC a déjà été largement utilisé par le passé et est considéré comme le capteur de référence dans le cadre de cette étude. Le capteur Wenglor YH08PCT8 est un capteur relativement simple, peu couteux qui est utilisé dans l'industrie pour détecter les très petites pièces, trous et encoches. Il est testé depuis déjà quatre ou cinq ans comme capteur de transport de sable ou de neige. Dans le cadre de cette étude nous nous concentrons sur les performances du capteur Wenglor en contexte de neige soufflée. Au cours de deux hivers consécutifs de 2011 à 2013 nous avons mis en œuvre les capteurs Wenglor et SPC au Col du Lac Blanc (Alpes Française 2700m) et nous avons testé le capteur Wenglor en chambre froide. Les résultats présentés ici porteront sur les performances du capteur Wenglor pour une utilisation en haute montagne et dans les régions polaires.

MOTS-CLEF : Transport de neige, Snow Particle Counter, Wenglor, capteur

ABSTRACT: Heterogeneity of snow cover in high mountain area may increase avalanche hazard. In Antarctica, drifting snow plays an important role in the surface mass balance and therefore on the sea level rise. It is therefore necessary to evaluate blowing snow in the field in terms of snow fluxes and occurrence, and, if possible, using to automatic measurements. We present here two sensors based on the same measurements techniques, using the optical beam obstruction method: the Snow Particle Counter (SPC) and the Wenglor YH08PCT8 sensor. The SPC has been widely tested and used in the past and is considered the reference in the present study. The Wenglor YH08PCT8 sensor is a relatively simple, inexpensive commercial counter used in industry which recognizes extremely small parts, holes, slots and notches. It has been tested for 4-5 years as a sensor for a eolian sand and snow transport. The present study focused on the performance of the Wenglor sensor in the context of blowing snow measurement. During two consecutive winters from 2011 to 2013, we set up Wenglor sensors and SPCs at Lac Blanc Pass (French Alps 2800 m) and tested Wenglor sensors in cold room. The results presented here will focus on Wenglor sensor's performance and limitations for uses in high mountain area and cold regions.

KEYWORDS: blowing snow measurement, SPC, Wenglor, sensor.

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1 INTRODUCTION

Several research and technical devices have been developed in the field of snow drift measurement (Bellot et al., 2010). These sensors can be separated into two categories: mechanical and automatic. The general principle of mechanical devices is to catch and weigh snow particles (Bolognesi et al.,1995), which precludes accessing continuous measurements over a long period. The automatic measurements are based on different physical principles. Some sensors are acoustic (Chritin et al., 1999; Cierco et al., 2007) and others are optical (Sato et al.,1993). In this study, we will focus on the optical methods. A recent study has been carried out using a Wenglor YH08NCT8 industrial sensor to measure drifting snow (Leonard et al., 2008, 2011). This sensor is used in industry for detecting holes, slots and notches. The special feature of this sensor is its sensitivity to small elements (40 to 60µm).This research aims at testing the capacity of this YH08NCT8 sensor to be used for drifting snow measurements. We used the Snow Particle Counter (SPC Nigata Electric) as a reference (Sato et al.,2011). This sensor has been used in several studies (see Font et al., 2001, for its metrological capability), and we will define the measurement uncertainty in this specific context.

2 EXPERIMENTAL DEVICE

The experiment was conducted at Lac Blanc Pass (Alpe d'Huez France 2700m). This test site has been used for several years to study snow drift (Naaim-Bouvet et al., 2012). The wind on this site is oriented essentially on the north-south axis. In this context, it is easier to interpret the data and orient a sensor properly. The measurement devices installed at the site include a 5-m-high mast with a snow depth laser sensor (SHM30 Jenoptik) at the top in front of an acoustic sensor (SR50 Campbell) providing the advantages of both technologies. Near this sensor are an ultrasonic anemometer and a SPC. Along the mast three SPCs can be attached at different heights, in front of three Wenglor sensors. The Wenglor (1) at the top can be oriented 180° with a windsock. The middle (2) sensor can be oriented 360° with a rotary electric connector. The third (3) is fixed and oriented for the flux coming from north or south (Figure 1). During the season, we remove this facility depending on the snow depth. The lowest sensors are located at 20-40 cm above the snow surface. At certain times, we use the middle SPC sensor attached in front of the lowest one to collect data to evaluate the dispersion between two measurement points as shown in Figure 1.

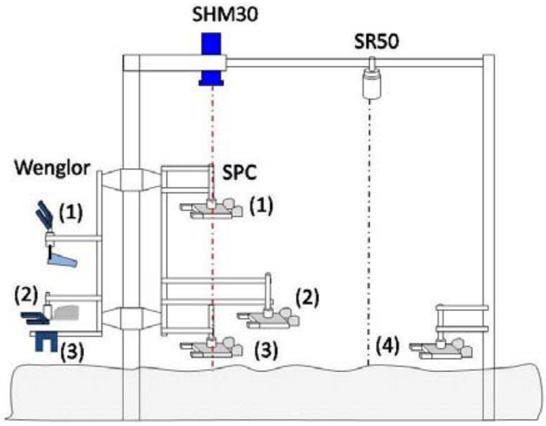

Figure 1. Experimental facility for snow drift measurement

3 SNOW PARTICLES SENSOR

3.1 Measurement principle

The measurement principle is based on the 500-µm-wide obstruction of the laser plan (Sato and Kimura, 1993). The obstruction generates a tension peak on the receiver, with the sizes of the peaks depending on the particle sizes (Figure 2). In this way, the snow particle counter detects particles with a mean particle size between 40 and 500 µm in diameter and divides them into 32 classes. Assuming spherical snow particles, the horizontal snow mass flux q is calculated as follows:

$$q = \sum q_d = \frac{\sum n_d \frac{4}{3}\pi\left(\frac{d}{2}\right)^3 \rho_p}{S * t} \qquad (1)$$

Where q_d is the horizontal snow mass flux for the diameter d, n_d is the number of drifting snow particles, S the sample area, t the sample period, and ρ_p the density of the drifting snow particles (917 kg m^{-3}).

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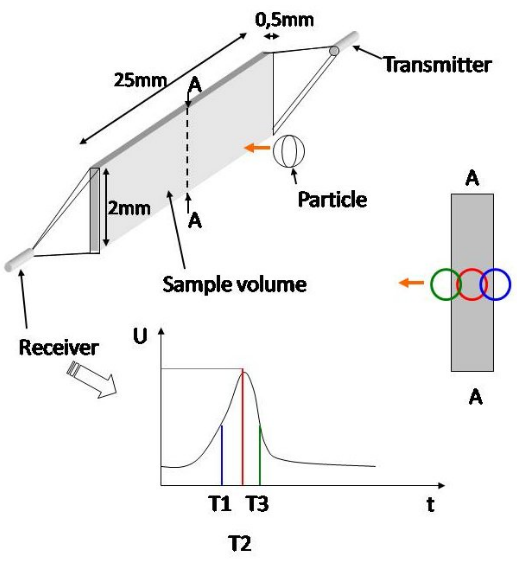

Figure 2.SPC measurement principle

3.2 Spatial disparity of the measurement

To compare two sensors, the disparity between two measurement points must be characterized. We used the data from both SPC (3 and 4 in Figure 2) sensors set up side-by-side. To compare the two sensors we calculated the ratio (R_i) between each sum of particle class for 10 minutes (n_i).

$$R_i = \frac{n_{iLeft}}{n_{iRight}} \quad (2)$$

We studied the resulting dispersion taking as reference the left SPC, which we used later for comparison with the Wenglor. Theoretically, both sensors are at the same height, but this is never exactly the case due to aeolian features such sastruggi. When considering low frequency (systematic deviation around one), the variation on the ratio was due to a height difference. We removed it as follows:

$$R_{ijFiltered} = R_{ij} - \frac{R_{ij-1} + R_{ij} + R_{ij+1}}{3} + 1 \quad (3)$$

with j the sample over time and i the class of particles (we remind that SPC allows to distinguish 32 classes of particles between 40 and 500 µm in diameter).

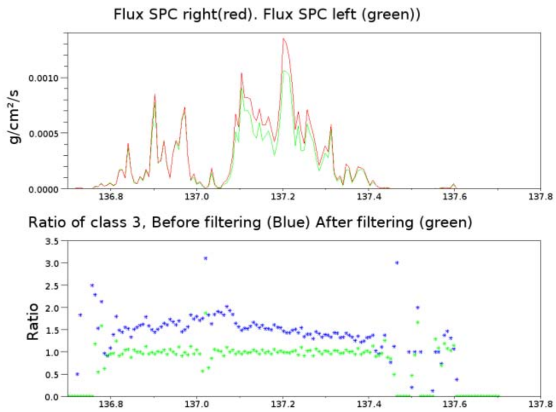

Figure 3. Example of an event and data processing (Class 3: 68 µm diameter)

On the data filtered, we determined the standard deviation on the ratio depending on the number of particles detected (any class confused with a sample of 100 $R_{jfiltered}$).

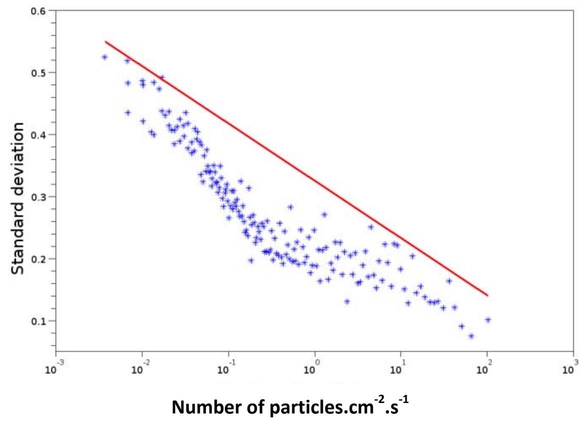

Figure 4. Standard deviation of the ratio as a function of the number of particles detected (blue) and the model (red).

To describe this dispersion (U(R) uncertainty on the ratio) as a function of the number of particles, we modelled it using the following equation in order to include as many data items as possible.

$$U(R) = a * \log(n_i) + b \quad (4)$$

with :
a= - 0.040107
b=0.3256013

Beyond 0.1 particle per square centimetre per second 85% of the ratio calculated during the intercomparison period was contained within these limits.

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4 WENGLOR SENSOR

The Wenglor sensor is simpler than the SPC. It is characterized by low power consumption (<1,2W) and it is easy to acquire its output (all-or-nothing type signal). This sensor is useful because it seems to be sensitive to small elements. The detection threshold reported by the manufacturer is a 40µm element. Assuming this element is a wire and the sample volume is a tube (diameter, 600µm) the detection threshold is a particle of 175µm in diameter.

$$d = 2 * \sqrt{\frac{0.6 * 0.04}{\pi}} \approx 0.175mm \tag{5}$$

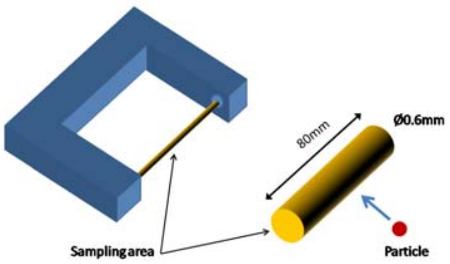

Figure 4.Wenglor measurement principle

Thus the sensor counts the number of particles in the snow drift flux greater than 175µm. We tested this threshold with the number of particles detected by the SPC in front of each Wenglor. We searched for the particle size for which we had the same number of particles detected between the SPC and the Wenglor, obtaining following threshold distribution (Figure 5) :

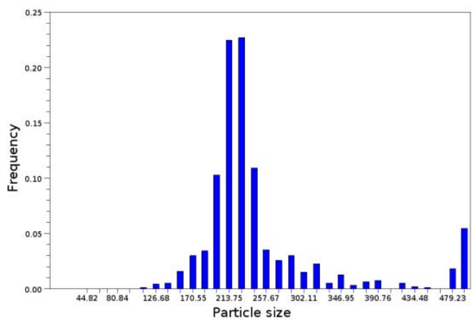

Figure 5.Threshold of the Wenglor sensor

To obtain this result we needed to select a short period of time in which we were sure that both sensors were at the same height (934 periods of 10 minutes). We did not use the lowest sensor for this test because it was too sensitive to height difference. Leonard et al. (2011) found a diameter between 224µm and 230µm. In this study, we obtained a threshold of 213µm which is of the same order of magnitude.

In a cold room we tested the sensor behaviour in terms of the temperature. We installed an experimental device with a wire continuously crossing the sample area of many sensors. Below a certain temperature, the sensor no longer meets. The critical thresholds varied widely between sensors (-12°C to -30°C).

Brightness also influences the sensor, but we have not yet clearly established its influence on the measurements. The maximum ambient light mentioned in the data sheet is 10,000 lux. A cloudy sky is typically between 500 and 25000 lux. Experiments are in progress on this topic in Antarctica.

5 COMPARISON OF THE TWO SENSORS

During the experimental period in which the SPCs are in front of the Wenglor sensor, we tested the accuracy of the Wenglor by calculating the ratio between the sum of particles counted by the SPC in the class equal to and greater than 213µm and the number of particles detected by the Wenglor during the same period. We compared these data with the dispersion model established between the two SPCs (Equation 4). We excluded the data when the temperature was below -12° and the data when the flux was below 0.1 particles per square centimetre per second. For the sensors at the top, 87% of the ratio was contained within these limits, 69% for the middle sensors and 42% for those at the bottom. For the sensors at the top, when the ratio could not be explained by the dispersion, the 10 minute periods were not contiguous. The same phenomena were found on the middle and bottom sensor, but sometimes these data were contiguous. We looked for other potential factors (Wind speed, wind orientation, temperature and luminosity) which could influence the results but found none. Consequently the particle size detection threshold of the Wenglor is too coarse to see very fine blowing particles and the undetected fraction of size distribution is important. To estimate the snow flux, this fraction must be added as a percentage of the calculated mass flux (Leonard and Cullater, 2008). Once the minimum observable diameter is known, some assumptions concerning size distribution must be made. Larger particles are being carried aloft at a higher wind speed, smaller particles are being carried aloft at higher altitude (Naaim-Bouvet et al., 2013). It becomes apparent that no universal calibration exists (Figure 6) and first, snow size distribution in the French Alps

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according to height, wind speed and snow type must be better known.

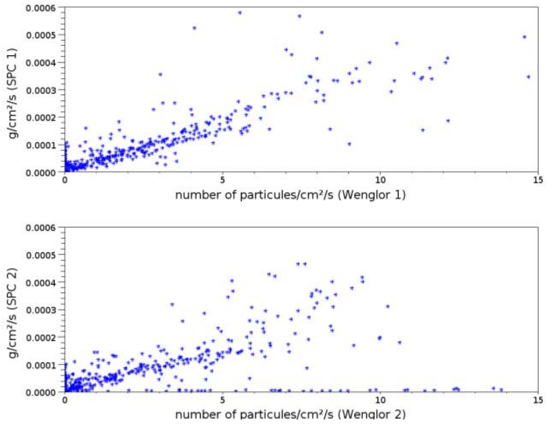

Figure 6. Relation between flux SPC and number of particles Wenglor for three day of data

6 CONCLUSION AND OUTLOOK

This study has shown the potential and the limits of industrial optical forks for measuring snow flux. The minimum diameter measured by Wenglor was around 213 µm, greater than initially expected (100 µm - Leonard and Cullather, 2008). Consequently the particle size detection threshold of the Wenglor is too coarse and the undetected fraction of size distribution is important. No universal calibration exists and to improve results obtained thanks to Wenglor snow size distribution according to height, wind speed and snow type must be better known.

7 ACKNOWLEDGMENTS

Funding for this experiment was provided by the European INTERREG ALCOTRA MAP3 project, and from the French national INEV and CENACLAM programmes. We extend our thanks to Xavier Ravanat and Frederic Ousset who provided assistance with fieldwork.

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